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CENTRIFUGE DEWATERING OF LIME TREATED SEWAGE SLUDGE

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OF LIME TREATED
SEWAGE SLUDGE

RESEARCH BRANCH
MINISTRY OF THE ENVIRONMENT

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CENTRIFUGE DEWATERING

OF LIME TREATED

SEWAGE SLUDGE

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Paper No. 2030

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SUMMARY

In connection with the lime treatment nutrient removal program at the Newmarket, Ontario WPCP plant, a two month raw sludge dewatering study, using a Sharples solid bowl centrifuge was undertaken.

Centrifuge variables, such as sludge feed concentration, sludge feed rate, sludge pH and differential RPM were examined.

The project was successful and the optimum results produced from centrifuging lime raw primary sludge were as follows:

(a) 98 - 99% Suspended Solids Removal

(b) Polymer dosages of less than one lb. per dry ton of solids

(c) Consistent centrate qualities of less than 700 ppm Suspended Solids

(d) Sludge Cake dryness of 27 to 34% w/w

(e) Feed to Centrate, Total Phosphorus reduction of 95%

(f) Centrate Total Phosphorus levels returned to the plant were in the order of 10 to 30 ppm

INTRODUCTION

I Historical Background

Many failures, arising out of mechanical design problems, kept the centrifuge very much in the background, until the late 1950's when promising dewatering projects using sewage sludges began to evolve.

Early models of the centrifuge, which were of the basket type, were used in Germany in 1907. Similar types with improved designs were introduced in the twenties.

The advent of the solid bowl concept, which was the beginning of the modern centrifuge era, was tested by the Dorr Company. This experiment took place in the 1930's, but with limited success, as centrate qualities were poor.

A disc-valve machine was tried at Sioux Falls, using waste activated sludge and accomplished 1% to 5% thickening. These trials were plagued with plugging problems; a common occurrence with centrifuges at this time.

In 1954, the Bird Company tested a unit similar to the one used by Dorr in the thirties. Digested sludge was dewatered, and cake concentrations of 20-35%, with 50 to 70% solids recovery were achieved. This centrifuge developed forces between 900 and 1500 G's, and had a bowl length-to-diameter ratio of 1.5.

It became increasingly significant to designers and investigators, that the bowl length-to-diameter ratio was an important design parameter. With extended bowls, the slurries had a longer residence, consequently giving the sludges more reaction time with resultant improved solids separation.

In 1964, the Dorr-Oliver Company introduced a long bowl centrifuge, with a length-to-diameter ration of 2.9.

Subsequently, in 1965 at Atlanta, the Sharples Company instituted a 10-month study involving the basket, disc and decanter styles of centrifuges. All types of sewage sludges were processed and polyelectrolyte additions were examined. Out of these experiments came a great deal of insight as to the value of polymer addition and the suitability of various designs of centrifuges for any given sludge.

More recently the Research Branch, of the Ministry of the Environment has been involved in projects at Brampton and Simcoe, Ontario using the Kruger solid bowl centrifuge with digester sludge. Generally, the results have been good and new technieques of polymer addition have been developed to give high quality centrates. As a result of these investigations, a full-scale centrifuge installation is underway at Simcoe, and other projects are being initiated by the Plant Operations Branch.

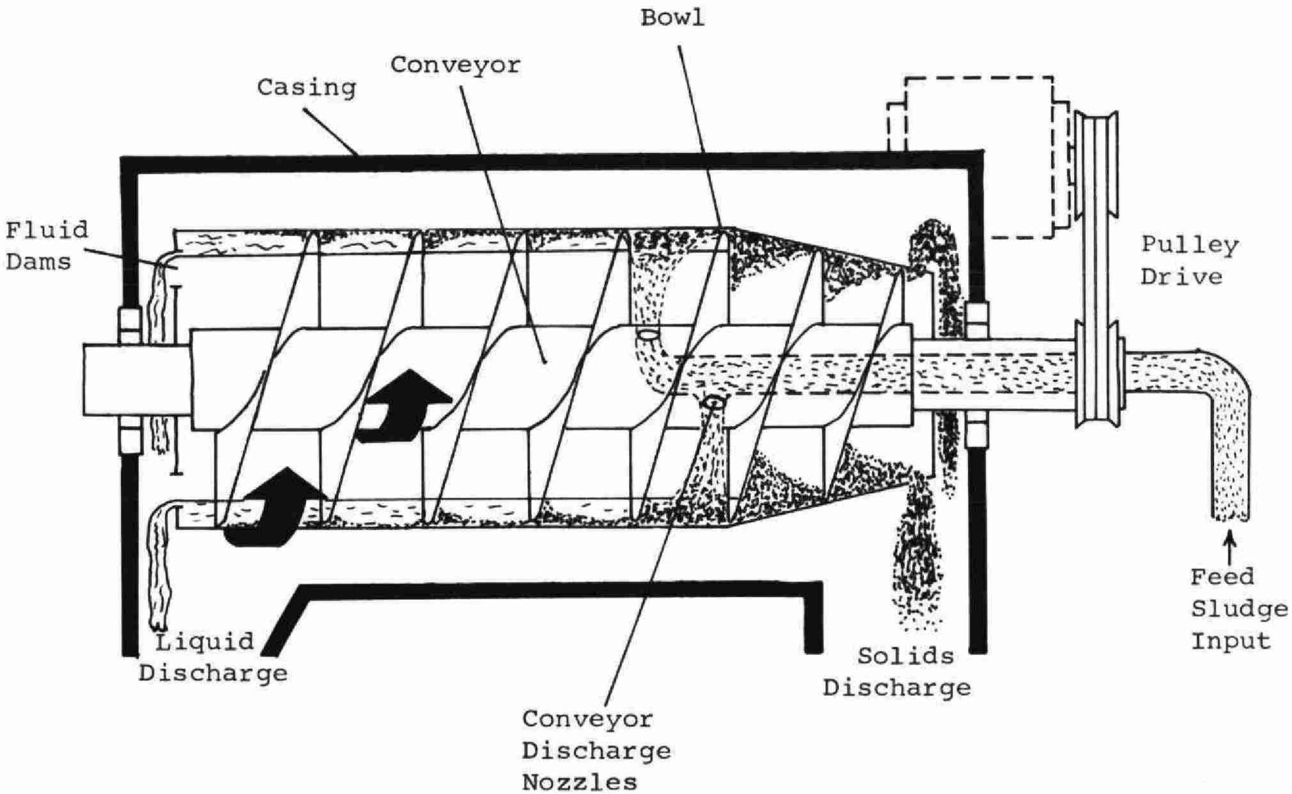
The transition of the centrifuge into the sewage treatment field has been a gradual one. Now with new materials and finer engineering, the contemporary centrifuge is proving to be a valuable tool in the sewage treatment plant.

Description of the Newmarket Centrifuge

The centrifuge used at the Newmarket project was a model P3000, Super-D-Canter, continuous solid bowl type, manufactured by the Sharples-Stokes Division, of the Pennwalt Corporation. The diagram in Fig. 1, illustrates the main mechanism of this machine.

The principles of operation are as follows:

1. The feed slurry enters via the feed inlet tube and is directed into the bowl through the conveyor discharge nozzles.
2. The bowl is connected to a high HP drive system, which in turn, spins the bowl clockwise at a given RPM. Centrifugal forces are developed and act on the slurry, driving the solid particles to the wall of the bowl.
3. The conveyor, which is driven by a geared mechanism, turns in the same direction as the bowl, but at a slightly lower speed. The blades of the conveyor move the spun solids on the bowl wall to the conical end of the reaction chamber, where the cake drops through the discharge outlets. Simultaneously the liquid phase is displaced in the opposite direction towards the liquid discharge openings.
4. Sludge retention time in the bowl can be altered by adjusting Conveyor-bowl Δ RPM. Adjustment of orifice plates changes the liquid depth of the bowl slurry.
5. Polyelectrolyte addition is usually made at the centrifuge entrance, or earlier in the feed system.



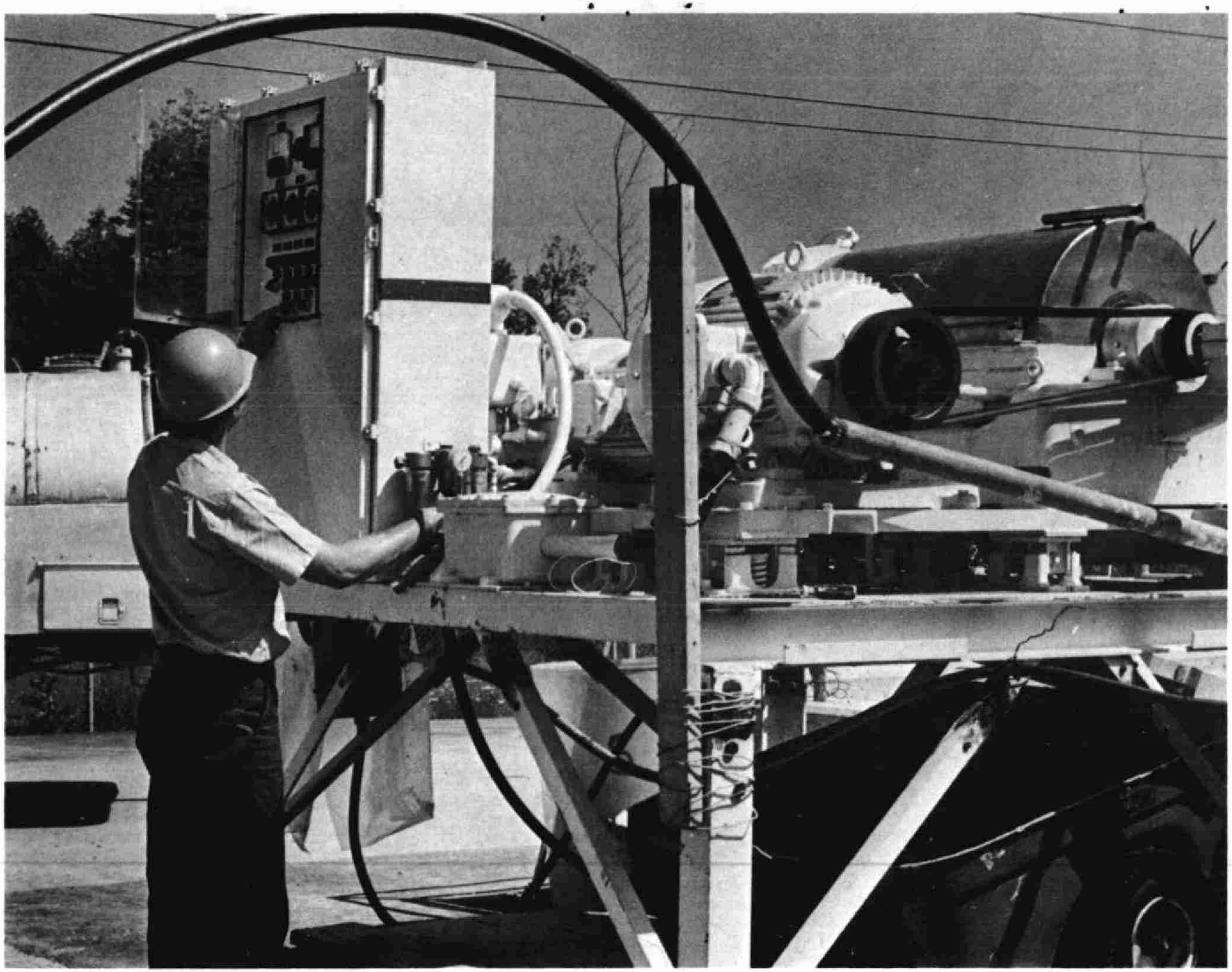
CENTRIFUGE OPERATION
MECHANISMS

Fig. 1	AGS	Jan. 1972

SHARPLES CENTRIFUGE STATISTICS

MODEL P3000 (with added equipment)

1. Feed rate - to 30 GPM
2. Bowl RPM - variable from 2000 to 4000
3. Bowl type - cylindrical conical
4. Bowl G. force - 3180 at 4000 RPM
5. Adjustable differential bowl-to-conveyor RPM



#1 Photo showing the Newmarket Centrifuge

The Newmarket Project

Plant Description

The Newmarket plant is a conventional activated sludge design, with two stage anaerobic digestion. Daily flows average 1.5 MG and after degritting, the raw sewage is treated with hydrated lime to a dosage of 200 ppm in a flash mixer.

The lime-sewage mixture is then settled in primary clarifiers, followed by mechanical aeration, final settling and chlorination. (See Fig. 2a)

Experimental Procedure

Raw sludge was drawn from the primary clarifiers via a large recirculation pump, then stored and mixed continuously in an open holding tank.

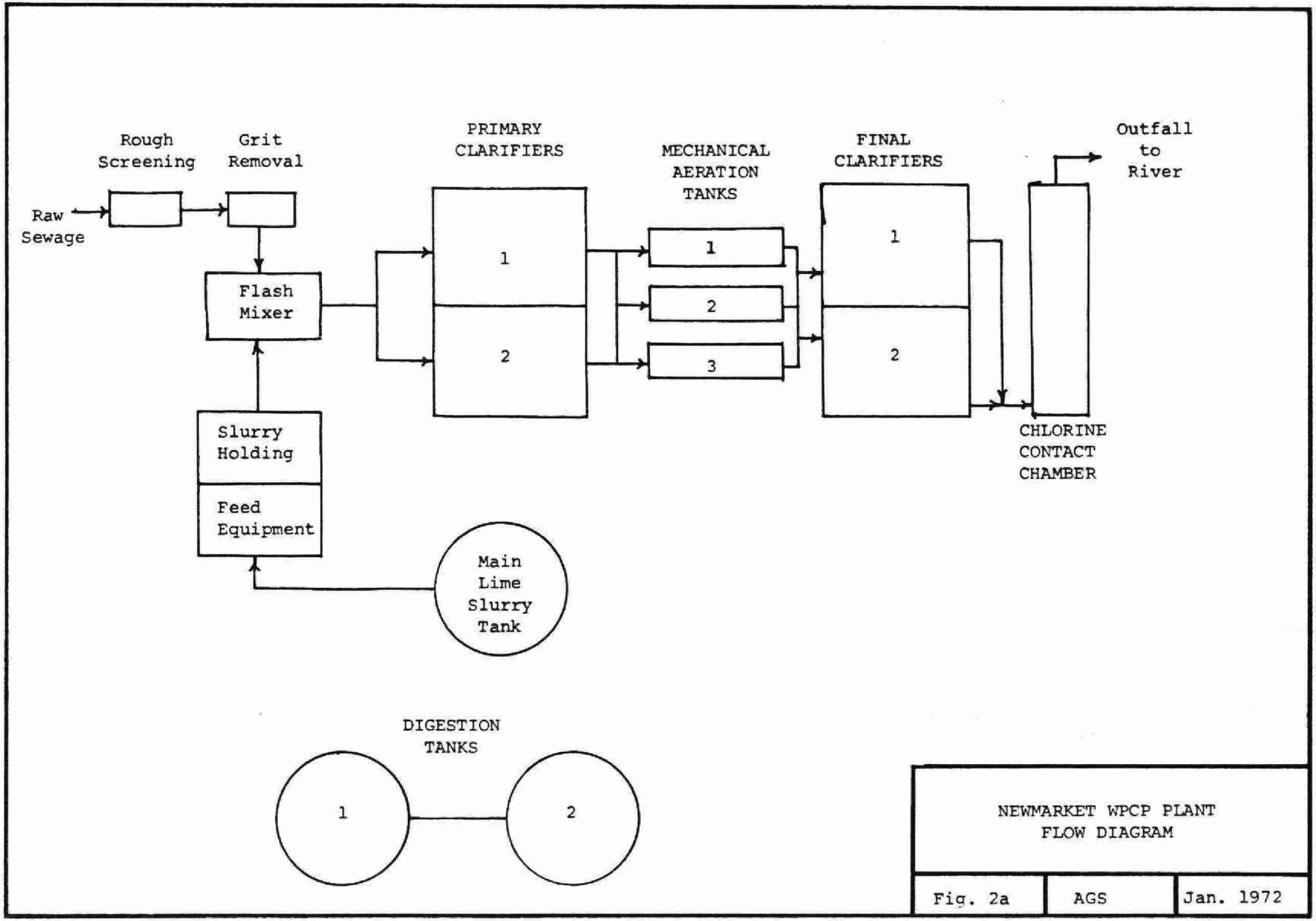
When needed, sludge thickening was accomplished by settling and supernating.

The mixed sludge was fed to the centrifuge by a varispeed Moyno pump and reacted with a polymer solution, at the centrifuge input.

Some short experiments involving polymer addition to the sludge while in the holding tank were initiated; the results of using this technique are discussed later in this report.

The sludge cake was collected in an open trailer which could be rolled underneath the centrifuge and the centrate was returned to the lime-sewage flash mixing tank. (See Fig. 2b)

Centrifuge variables such as sludge concentration, feed rate, polymer type and dosage, bowl RPM, and differential



NEWMARKET WPCP PLANT
FLOW DIAGRAM

Fig. 2a	AGS	Jan. 1972

RPM were examined. Test runs normally took from 5 to 15 minutes at each variable or until no further change was noticed in the centrate appearance. Longer runs of two hours duration were performed at optimum conditions.

Samples of feed sludge, cake and centrate were collected simultaneously at frequent intervals throughout each experimental run, and chemical analyses were performed the following day.

The results of these trials are as follows:

Centrifuge Results

I SOLIDS REMOVAL

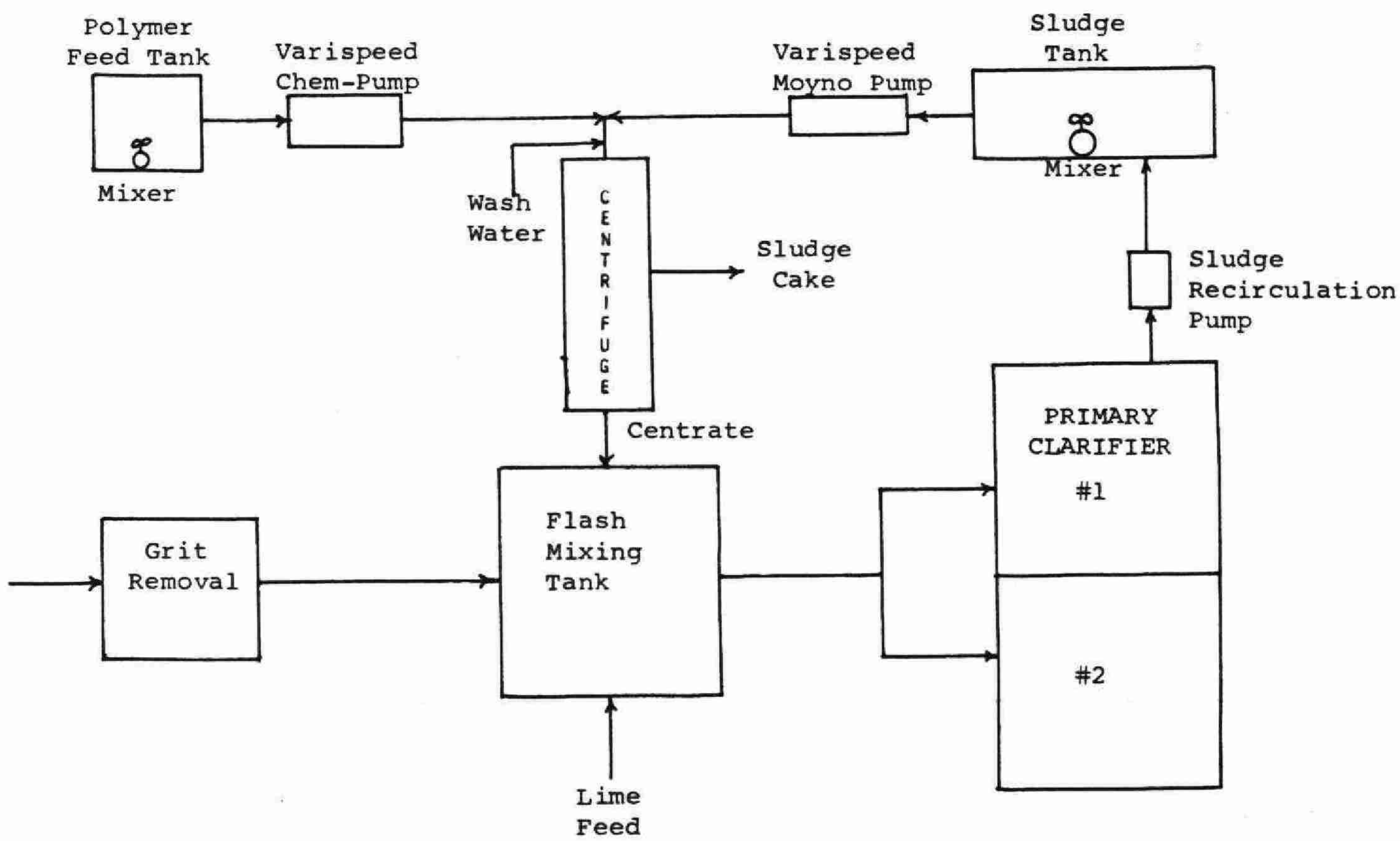
Without Polymer Dosage

Compiled from a series of eleven runs over a wide range of sludge pH's, a baseline evaluation of centrifuge performance was indicated, as seen in Table I. Good cake concentrations were produced, with moderate solids removal, but poor centrate qualities were obtained.

Table I

Average Values

Feed Rate IGPM	Sludge Conc. %	Cake Conc. %	% Susp. Solids Removal	Centrate % Susp. Solids
17.6	5.2	32.6	78.2	1.33



IN PLANT CENTRIFUGE ARRANGEMENT.

Fig. 2b	AGS	Jan. 1972

2. <u>Differential Test</u>

A test was performed with the lime-treated raw sludge at various bowl-to-conveyor differential RPM. Constants in this test were as follows: Bowl speed at 3250 RPM, sludge pH of 9.2, feed rate at 15 IGPM and sludge concentration of 4.7% w/w Susp. Solids. Table 2 shows the results of this test.

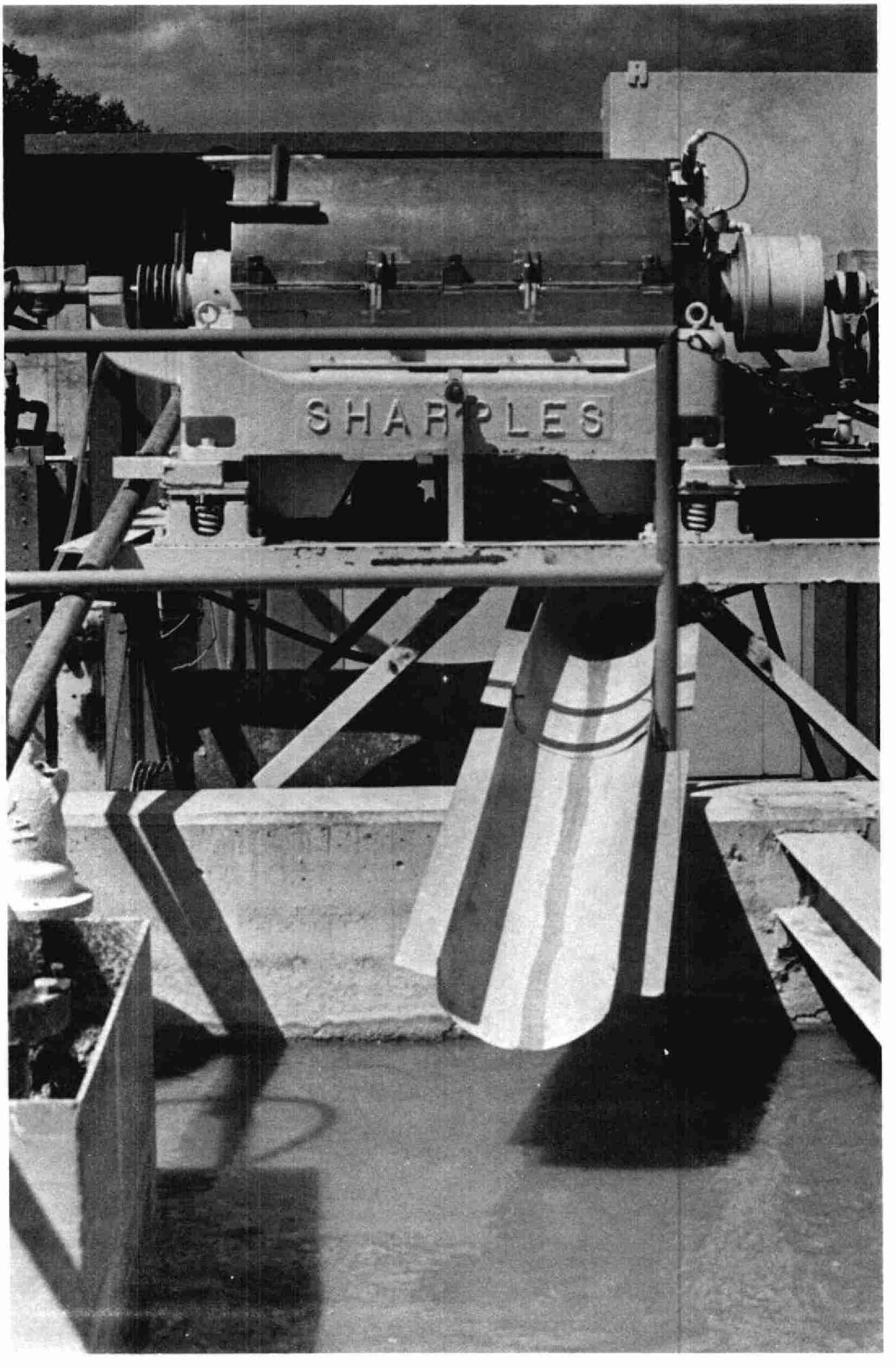
Table II

Differential test

RPM Δ	% w/w Cake Conc.	% w/w Susp. Solids Removal	% w/w Centrate Susp. Solids
13	30.9	83.9	0.75
20	29.1	82.5	0.95
27	29.5	81.4	1.10
34	26.5	78.6	1.02

Although considerable suspended solids reduction and dry cake could be achieved without the addition of polymer, the centrate quality still remained poor.

Quantitative reductions in centrate solids were made by lowering the differential RPM, but in some cases conveyor overloading was experienced. The optimum value of 27 differential RPM was used for most of the project.



#2 Newmarket Centrifuge showing
Centrate return to lime-sewage mixing tank

3. With Polymer Dosage

The centrifuge operation using polymer naturally improved the efficiency of the solids separation.

A high-charge anionic polyelectrolyte (Percol 726) was employed at a solution concentration of 0.12% w/w.

Figure 3 illustrates that the addition of Polymer increased the suspended solids reduction upwards to 15% over the values produced from runs without polymer.

Parallel results were indicated in centrate qualities as seen in Figures 4 and 5; but with some sacrifice in cake dryness. Moreover, sharp improvements were noticed in centrate clarity, with relatively small increases in polymer dosages.

4. Effects of Raw Sludge pH

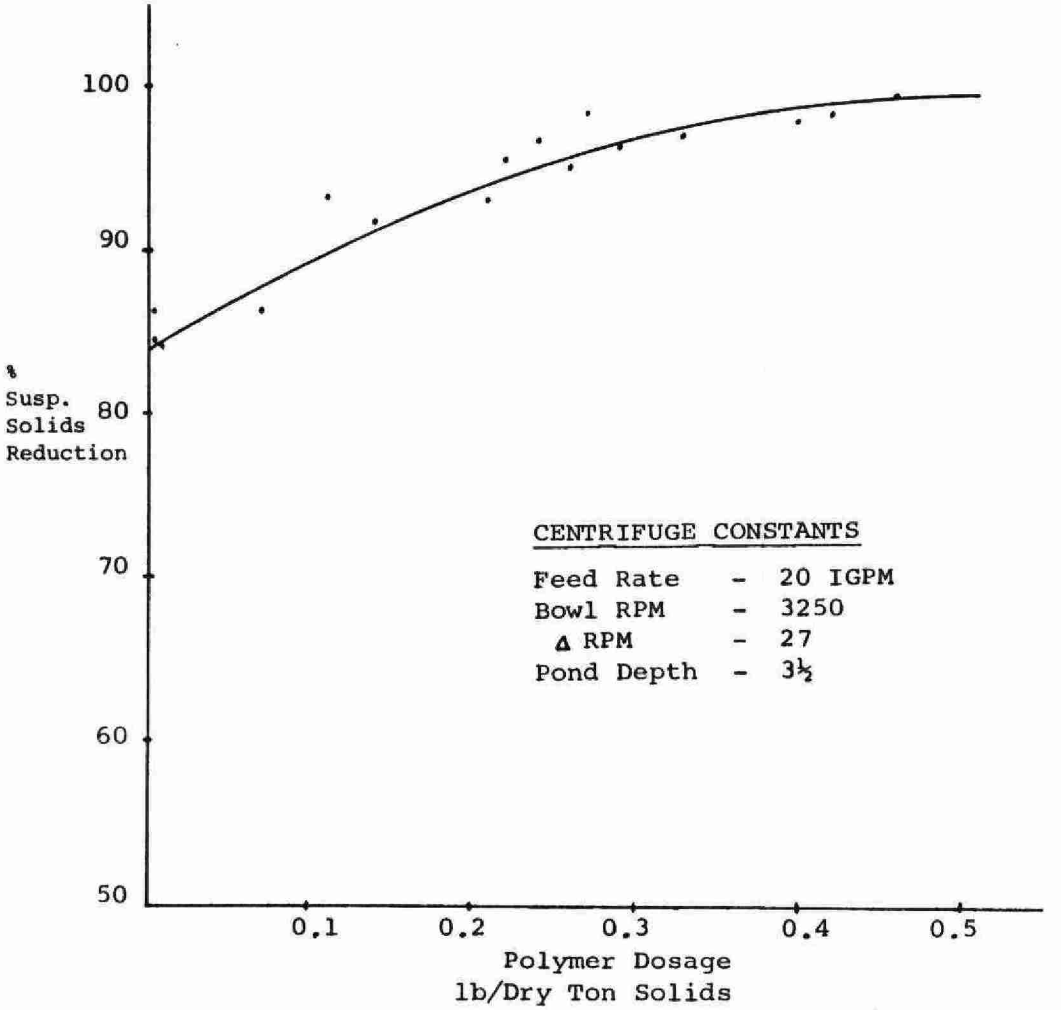
The individual run plot in Figure 5 denotes the significance of sludge pH on centrifuge performance.

There were many factors which caused variability in the sludge pH, (such as raw sewage pH and lime dosage) but the most prominent one was that of sludge holding time. (See Table III)

Table III

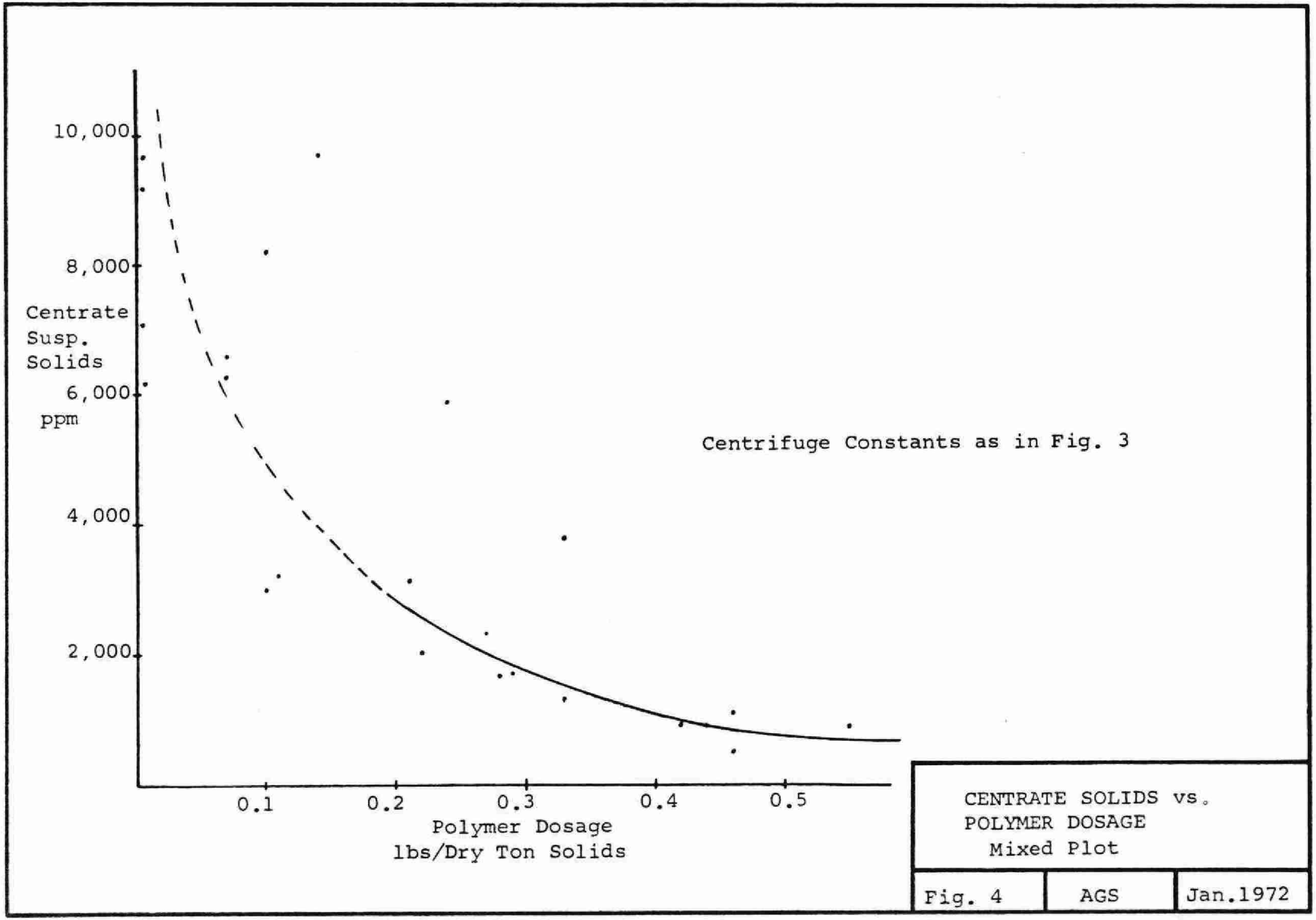
Raw Sludge pH Changes

Starting pH	Hours Retained	Resulting pH
9.2	24	8.5
9.2	48	7.9
10.1	24	9.2
10.6	24	8.6
11.6	24	10.2



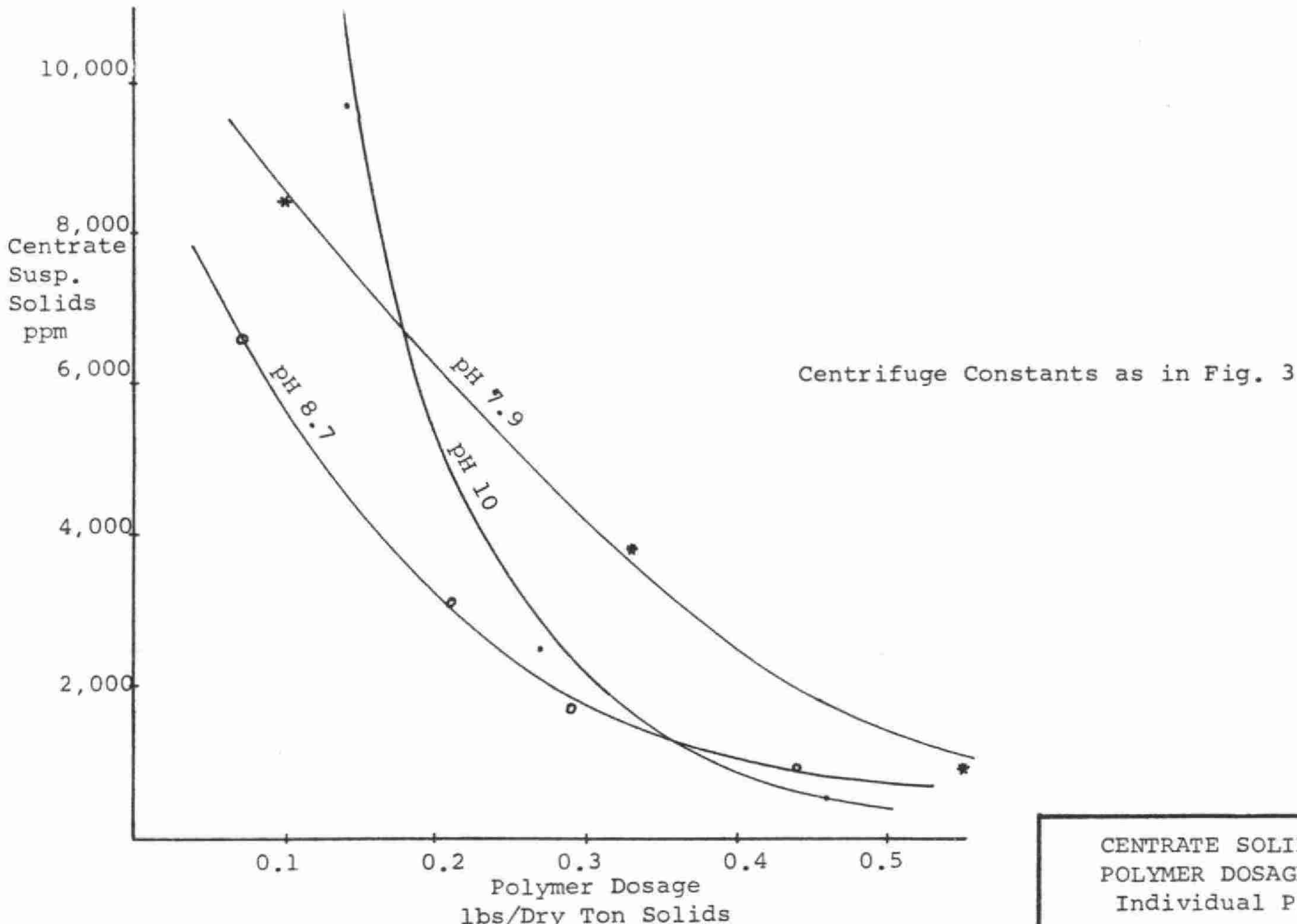
SOLIDS REDUCTION Vs.
POLYMER DOSAGE

Fig. 3	AGS	Jan. 1972



CENTRATE SOLIDS vs.
POLYMER DOSAGE
Mixed Plot

Fig. 4	AGS	Jan.1972



CENTRATE SOLIDS vs. POLYMER DOSAGE Individual Plot		
Fig. 5	AGS	Jan.1972

In every case when the raw sludge was retained in the holding tank, without any subsequent addition of fresh sludge, the pH fell and continued to fall. This phenomenon was further investigated in the laboratory under anaerobic conditions, and the sludge pH in almost all cases dropped to an average value of 7.6, over a period of six days.

The most evident improvements given by the 10.2 pH sludge can be observed in the drier cake values with lower suspended solids in the centrates. Reproduction of results were attained in the two runs with a sludge pH of 8.7, even though the second experiment was done at a bowl RPM of 2500.

The effects of sludge pH on centrifuge performance were not studied extensively, but certain patterns did form as the project proceeded.

It seemed that a pH of approximately 10 was the ideal level for overall good centrifuge results. This value of pH was also found to be optimum by Kyte, in his work in a California lime treated plant (personal communication).

The total effects of sludge pH can be seen in Table IV.

Table IV

Newmarket Centrifuge Study

Raw Primary Sludge Plus Lime

Sludge pH	Susp. Solids Removal % w/w	Polymer lb./ton Dry Solids	Total Phosphorus Removal %	Effluent Solids %	Cake Solids w/w %
10.2	99.6	0.46	93.0	0.050	33.9
	98.5	0.27	30.3	0.226	34.8
	96.5	0.24	32.4	0.591	36.5
	91.9	0.14	63.8	0.974	36.7
7.9	97.9	0.55	--	0.087	30.3
	91.8	0.33	--	0.383	33.1
	83.0	0.24	--	0.638	32.7
9.8	95.2	0.29	--	0.166	28.5
	91.5	0.10	--	0.300	33.2
	91.4	none	--	0.416	35.6
11.2	95.4	0.57	--	0.240	29.2
	94.9	0.36	--	0.390	28.9
	87.5	0.23	--	0.570	27.7
9.8	98.7	2.17	92.8	0.060	27.9
Polymer	98.7	0.98	89.0	0.060	26.0
Overdosing	98.4	0.44	99.5	0.080	23.9
8.7	98.0	0.44	95.2	0.090	27.5
	96.4	0.29	94.5	0.170	24.4
	93.0	0.21	63.0	0.310	28.8
8.7	98.3	0.42	94.5	0.090	25.8
Centrifuge	97.0	0.33	92.3	0.130	25.5
RPM 2500	95.6	0.22	84.0	0.200	23.6
	93.3	0.10	66.7	0.320	23.9
	86.5	none	9.3	0.620	29.5

5. Polymer Overdosing

Polymer overdosing was incorporated into various runs to see how pure a centrate quality could be produced. Some improvement in centrate suspended solids and cake dryness was achieved, but foaming in the centrifuge effluent indicated that too much polyelectrolyte was escaping. Moreover, there seemed to be a saturation point where no additional amount of polymer dosage produced a better centrate. This point in most cases gave between 370 and 600 ppm suspended solids in the centrate, depending on sludge conditions.

6. Feed-to-Centrate Phosphate Reduction

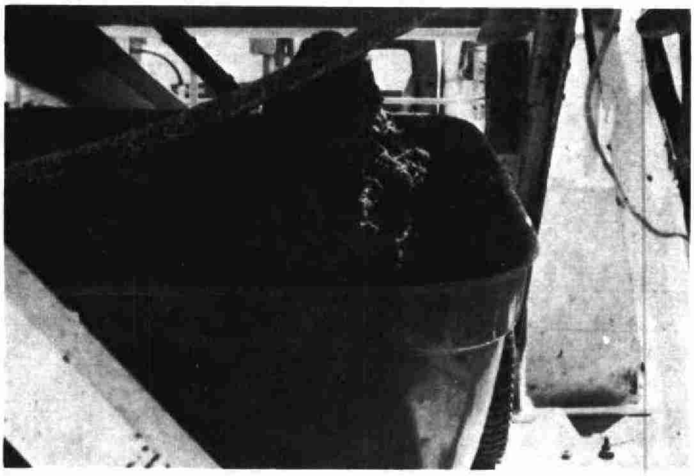
The data shown in Table 5 are the extractions of total phosphorus from feed to centrate during centrifugation of 4% sludge.

Table V

Centrate % Susp. Solids w/w	Total Phosphorus ppm Feed	Total Phosphorus ppm Centrate	Total Phosphorus Reduction %
0.970	750	400	46
0.890	810	395	51
0.506	405	120	63
0.142	400	67	83
0.080	600	23	90
0.060	620	19	97

As seen in Table 5, decreasing centrate solids by polymer addition also reduced phosphorous concentration in a direct relationship. Furthermore, lower values were easily attainable and maintained so that levels of phosphorous returned to the sewage process were consistently below 30 ppm.

#3 Photo of Centrifuge samples
feed, cake and centrate



#4 Newmarket Centrifuge
cake collection arrangement

6. A short Additional Polymer Study

Questions arose during the project as to the benefits of adding polymer directly to the raw sludge in the holding tank. Consequently, experiments were instigated using both anionic (Percol 726) and cationic (Prestol 444K) Polymers. The data from these investigations are presented in Table 6.

Centrifuge Constants for all tests

RPM 3250

Diff. RPM 27

Sludge pH 9 to 9.8

TEST A

Procedure

Cationic Polymer 0.012% solution was mixed with raw sludge. The 0.12% solution of anionic polymer was added at the centrifuge input as usual.

TEST B

Procedure

Same as test A only anionic polymer was also added to the sludge.

TEST C

Procedure

Cationic and anionic polymers mixed in the sludge tank and cationic polymer added at the centrifuge input.

Table VI

TEST A

Suspended Solid Conc. % w/w				lbs. Polymer/Dry ton Solids		
Feed Conc.	Cake Conc.	Centrate Conc.	Solids Removal	At Centrifuge	In Holding Tank	
				Anionic		Cationic
5.40	33.1	1.42	77.0	none		0.09
5.34	31.5	1.15	81.4	0.08		0.09
5.19	33.2	0.95	84.3	0.14		0.10
4.74	28.0	0.53	90.6	0.40		0.11
5.29	28.1	0.35	94.6	0.66		0.09
TEST B				Anionic	Anionic	Cationic
3.00	23.8	0.165	95.2	0.26	0.01	0.83
2.97	23.9	0.133	96.2	0.89	0.02	0.90
2.97	23.0	0.060	98.2	0.99	0.02	0.87
2.95	2.10	0.064	98.1	1.29	0.02	0.98
TEST C				Cationic	Anionic	Cationic
3.36	19.8	0.264	93.4	0.63	0.03	0.56
3.18	22.8	0.142	96.1	1.12	0.02	0.92
2.91	22.9	0.069	97.9	1.23	0.05	1.02
3.13	21.9	0.060	98.4	1.74	0.02	0.92

In general the three tests, relative to earlier runs, provided no improvement in cake dryness or centrate clarity. If anything, the process just became more complex with the addition of polymer to the sludge tank, and was less adaptable to a full-scale arrangement.

DISCUSSION

1. Using the Sharples P3000 Super-D-Canter centrifuge, solids recovery and cake dryness could be attained to some degree with unconditioned lime treated sludge. Augmentation with polyelectrolytes showed increased overall solids reduction and vast improvements in centrate quality.

2. Effect of centrate recycling

There has been some suggestion from investigators that continuously recycling of centifuge centrates through a plant, would cause upsets due to an accumulation of fines.

Contrary evidence to this belief can be found in studies by Kraus & Longley, (7) who operated a disc type centrifuge during a 147 day test, with only 76% solids recovery. The only effect of the centrate solids on the plant was that of a rise in Sludge Volume Index (SVI) in the aeration section. This initial increment in SVI levelled off and no further detrimental effects on the sewage plant were noticed.

Similar observations were made by Griffen and Brown. (4) Centrifuging digested sludge, at a solids recovery performance of 76.2% over a period of 2 years, caused no detrimental effects on the sewage plant.

No adverse effects were noted on the Newmarket plant process, although the experimental runs were somewhat intermittent.

These studies would indicate that the centrate qualities achieved at Newmarket would probably not have any serious effects on the plant operation. Centrate suspended solids of 700 to 500 ppm of less must be maintained to acheived values of phosphates returned

to the plant equal to or less than raw sewage levels.

3. Sludge pH

The importance of sludge pH in centrifugation cannot be ignored. Even if only 5% improvement can be noticed with optimum pH runs, the value of controlling this parameter over a period of years could lead to reduced costs of polymer and better all around performance.

Since the pH of the sludge drops on standing, it may also be advantageous to keep the size of the sludge holding tank in a lime treated plant to two or three days retention with an additional holding chamber in case of centrifuge breakdown. This smaller holding tank, would keep the sludge pH at a level suitable for centrifugation, due to its shorter retention period, and would be more practical for polymer addition or pH adjustment, if needed. As a supplement, the centrifuge operator could stock a selection of polymers, each one having an optimum efficiency in any given sludge pH range.

4. Polymer Overdosing

Polymer overdosing in centrifugation must be avoided, particularly if the centrate is fed back to the plant. The only time any problems were experienced with the plant operation, was when a considerable amount of polyelectrolyte escaped back into the system. As a result the aeration activated sludge became light and hard to settle.

One might expect that escaping polymer in the centrate would benefit the plants' sludge settling, but very often the reverse is true. Polymers that perform well under centrifuge conditions

may exhibit poor settling in the clarifiers.

5. Feed Rate

Although an ideal feed rate of 20 IGPM was found to be optimum in these experiments, higher rates of up to 40 IGPM were tried. The centrifuge operated well mechanically under these loadings, but the centrate quality depreciated somewhat, in comparison to previous runs with lower rates.

Therefore, when purchasing a centrifuge, it would be desirable to match the middle of the centrifuges' feed rate range to the amount of sludge to be processed per unit of time.

This tailoring of the centrifuge to plant conditions is crucial, because of day-to-day differences in plant sludge production. Consequently, when considering a centrifuge installation, a complete survey of the sludge conditions and volumes, including plans for plant expansion, must be carried out.

6. Sludge Cake Disposal

The bulk of semi-wet, fibrous cake produced by the centrifuge, renders a considerable decrease in the cost of sludge hauling.

Presently at Newmarket, four truck loads per day (40 cu. yds) of 8% raw plus secondary sludge are being trucked away to local farm lands. A calculation was done on the quantity of 30% cake that would be produced by the centrifuge based on an 8 hour a day operation. It was calculated that one truck load of sludge cake per day would be the equivalent amount.

Some problems may be encountered with the depositing of sludge cake on land for cultivation. Observations made of cake patches left in a field to dry, were that the cake continued to dry quickly and flaked. With this dehydration, the sludge nutrients may not have enough time to leach into the soil, particularly in the summer months when precipitation is lower.

To counteract dehydration, the sludge cake could be worked into the soil immediately on receiving or the cake mixed with peat moss and stored in a compost tank until needed.

CONCLUSIONS AND RECOMMENDATIONS

This study verifies that good quality cake and centrate can be obtained by centrifuging lime treated raw sludge, with small amounts of anionic polymer, and that the resultant decrease in sludge volume constitutes a substantial saving in sludge haulage. Therefore it is recommended that the centrifuge be considered as a sludge dewatering device for present and future lime treated sewage plants.

Appendix

Centrifuge Calculations

1. % W/W Solids Removal $= \frac{c(f-e)}{f(c-e)}$

   f = feed sludge suspended solids concentration W/W

   e = Centrate Suspended soldids concentration W/W

   c = cake concentration W/W

2. Feed Rate $= \frac{E(c-e)}{(c-f)}$

   E = centrate rate in GPM

3. G Force

   $G = 1.42 \times 10^{-5}\ (D)\ (RPM)^2$

   D = Bowl diameter in inches

4. Polymer Dosage lbs/Ton

   $$\text{lbs/Ton} = \frac{P \times P_c}{F \times F_c} \times 2000$$

   P = Polymer feed rate

   P_c = Polymer concentration

   F = Sludge feed rate

   F_c = Sludge concentration

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